# HYDROGEOLOGICAL EVALUATION OF GROUNDWATER AROUND BAUCHI AREA, NE NIGERIA.

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## ABSTRACT

An investigation of soils in Bauchi area has been carried out. The results of the investigations indicate the occurrence of two aquifer units namely; the unconsolidated weathered overburden aquifer unit and the fractured basement aquifer unit. The hydraulic parameters of the aquifer units indicate a mean hydraulic conductivity value of 2.99 $x10^{2}$m/day and a mean transmissivity value of 2.002 x $10^{1}$m/day. An average linear groundwater velocity of 4.21m/yr and a specific discharge of about 1.89m/yr were recorded. The groundwater has pH ranging from 6.90 to 7.10 implying that the groundwater sources are alkaline. The mean values for chloride, sulphate and iron are 158.89mg/l, 95.78mg/l and 8.70mg/l respectively. While the mean value for hardness is 381.29mg/l. These parameters indicate presence of mineral suphate, corrosion and very hard water therefore should be treated before use. Generally, erosion control structures in the area should be made of materials that should resist staining, corrosion and incrustation.

**Keywords:** Water, Hydraulic conductivity, Transmissivity, Basement, Aquifer, Bauchi.

## INTRODUCTION

The Bauchi area falls between latitudes 10º00′ and 10º30′ N and longitudes 9º30′ and 10º00′E (Fig. 1). It is easily accessible through Bauchi – Jos, Bauchi – Kano and Bauchi – Maiduguri roads. Other access routes are Bauchi – Tafawa Balewa and Bauchi – Gombe roads. It is located in the high relief of Bauchi and the run-off is relatively high, while the infiltration rate is low. The geological features, in addition to the adverse climatic condition of the area, control the groundwater storage. The surface waters in the study area are seasonal. There is the need therefore to exploit the groundwater resources. The area is underlain by crystalline basement complex, where the occurrence of groundwater is due largely to the development of secondary porosity and permeability by weathering and/or fracturing of the parent rocks (Acworth, 1987; Olorunfemi and Fasuyi, 1993 and Edet and Okereke, 1997).

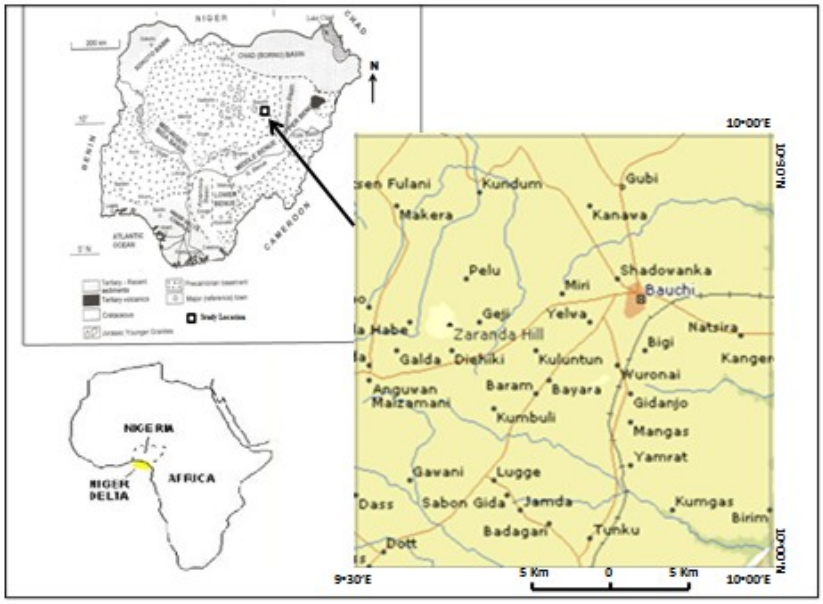


Fig. 1: Map showing location of the study area (In-set: Geological map of Nigeria and Africa).

Experience all over the World has shown that the rate of failure of boreholes is usually highest in the basement complex terrain. This is due to an inadequate knowledge of the basement aquifers, which results from in-situ weathering and/or denudation of basement rocks.

The rainfall in the study area begins around April and ends in October. In some years (such as 1988, 1990, 1991 and 1992), however, April and May lapsed into October. Highest rainfall occurs in the months of July, August and September. The mean monthly rainfall from 1987/1988 to 1993/94 water years varied from 0.1mm in February to 312.9mm in August with mean annual

value of 1029.5mm recorded. The months of July and August generally recorded the heaviest and also the greatest number of rainy days. The rainfall intensity, frequency and duration is higher in the mountainous parts of the study area than the lowlying areas. Thus the mean rainfall varies from 1000mm to 1300mm.

Previous work in the area involving groundwater investigation dates back 1928 when the Geological Survey of Nigeria commenced the hydrogeological investigation in Nigeria. They undertook the actual exploitation of groundwater for rural communities by means of hand-dug and concrete-lined wells. Then in 1947 the exploitation aspect of the water supply work was handed over to the public works department but the responsibility for making systematic studies of the distribution of groundwater remained with the Geological Survey.

Carter et al. (1963), published maps and description of the geology of parts of Northeastern Nigeria which includes the Adamawa, Bauchi, and Borno province. This forms the basis for further groundwater studies around the area. Subsequently, Du Preeze and Barber (1965) and Kiser (1968) gave some details on the chemical quality of groundwater of the old Northern Nigeria which includes the study area. This paper tends to provide the hydrogeological characteristics of the aquifer in the area such as the aquifer units and their parameters, hydraulic head distribution, recharge and discharge areas.

## GEOLOGY OF THE AREA

Rocks of the crystalline basement rocks of Nigeria underlie the study area. These include the Bauchite (Fayalite-quartz-monzonite); the biotite-hornblende-granite; the porphyroblastic biotite-granites, granulites and undifferentiated migmatites and gneisses (Fig. 2). The weathered overburden materials consisting of laterite, clays, sands and gravels cover most parts of the study area. The unconsolidated weathered overburden materials are of two types namely; the Alluvium and the Elluvium. However, outcrops of fayalite-quartz-monzonite (Bauchite) and biotete-hornblende-granite occur at two locations such as Idi and Lush hills.

Outcrops of these rocks show that they have been fractured due to tectonism. Thus fractures, fissures, joints and fracture-zones exist in places. The prominent fault zones trend towards the NE-SW and N-S zones as illustrated by Oyawoye (1970).

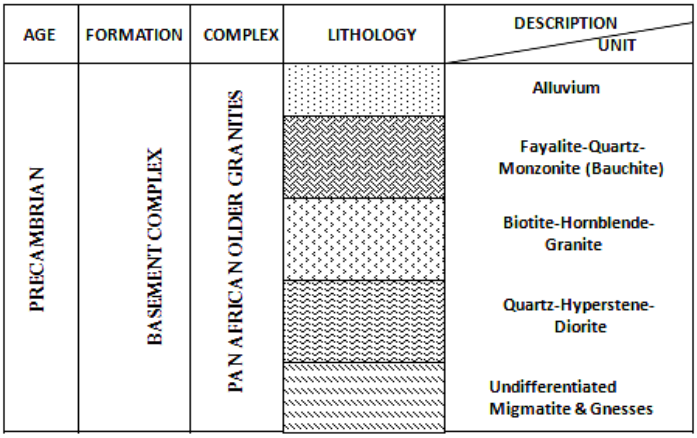


Fig. 2: Showing sediments formed from the weathered basement rocks in the study area.

## MATERIALS AND METHODS

The hydrogeological studies were carried out in three stages. The first stage involved literature review and reconnaissance field trips during which topographic maps were used in the identification of the rock types and their structures. Borehole records and pumping test results were collected from the Federal Ministry of Aviation and the Upper Benue River Basin Development Authority, Yola. The second stage involved detailed surface and sub-surface hydrogeologic studies during which depths to static water levels in wells were measured and water samples collected. Physico-chemical analysis of the samples was done in the laboratory employing Atomic Absorption Spectrophotometer for cations and conventional titration for anions. Ions were converted to milli-equivalent per litre and anions balanced against cations as control check on the reliability of the analysis. The last stage was interpretation of hydrogeological results in the study area.

## RESULTS AND DISCUSSION

From the analyses of borehole logs, the fractured basement aquifer thickness varies between 14m at BA5 to 52m at BA4 with an average thickness of about 28.57m (Table 1, Fig. 3). It underlies the weathered aquifer unit. All boreholes tap their water from this aquifer. The hydraulic properties of the seven boreholes penetrating the fractured aquifer as determined from pumping test method indicate a mean hydraulic Conductivity (K) value between of 0.12 and 2.31 m/day and a mean transmissivity (T) value ranging between 4.32 and 46.29 $m^2$/day (Table 2). Obiefuna and Nur (2003) carried out hydrogeological and geotechnical study of the present area of study,

Table 1: Computed hydraulic conductivity (K) and transmissivity (T) from borehole data.

| Borehole N0. | Depth to Water | Total Depth (m) | Aquifer Thickness (m) | Hydraulic Conductivity (m/day) | Transmissivity ($m^2$/day) |
|---|---|---|---|---|---|
| BA-1 | 6.42 | 129.00 | 36.00 | 0.12 | 4.32 |
| BA-2 | 2.52 | 149.00 | 20.00 | 0.27 | 5.40 |
| BA-3 | 6.20 | 96.00 | 32.00 | 0.38 | 12.16 |
| BA-4 | 4.35 | 96.00 | 52.00 | 0.28 | 14.56 |
| BA-5 | 2.33 | 65.00 | 14.00 | 1.75 | 24.50 |
| BA-6 | 2.95 | 54.00 | 20.00 | 2.31 | 46.20 |
| BA-7 | 4.09 | 56.00 | 26.00 | 1.27 | 33.02 |
| **Average** | 4.12 | 92.14 | 28.57 | 0.91 | 19.88 |

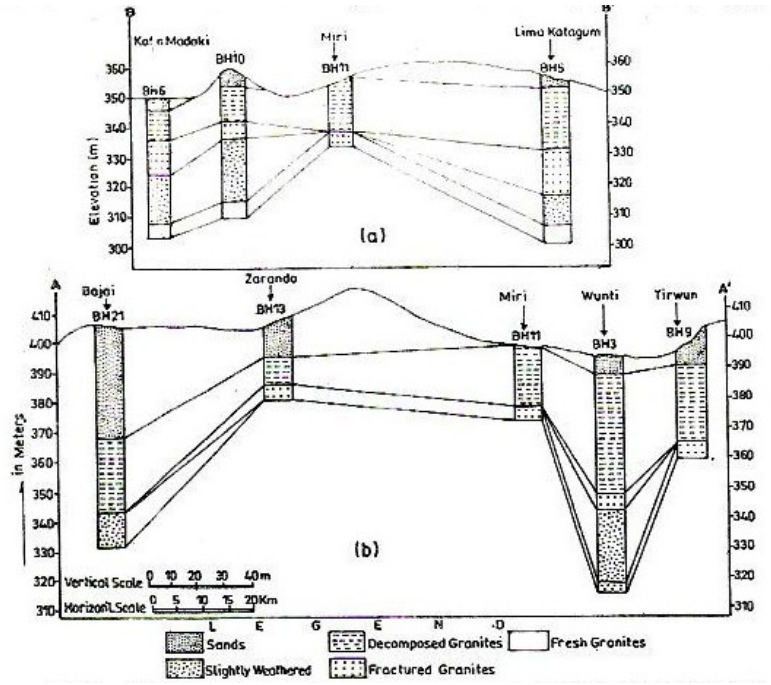


Fig. 3: Correlation of borehole lithologic logs in the study area.

and determined the hydraulic properties of thirteen hand-dug wells using the statistical grain-size methods of Hazen (1893), Harleman et al. (1963) and Uma et al. (1984), which indicate a mean hydraulic conductivity (K) value of 3.4 x $10^{-3}$ m/s and a mean transmissivity (T) value of 5.47 x $10^{-1}$ m/s (Table 2). Geochemical analyses of water samples collected from nine hand-dug wells are summarized in Table 3. The sodium and magnesium contents varied between 35-60mg/l and 45-85 mg/l respectively. The contents of sulphate range between 85 and 110 mg/l, while the

Table 2: Hydraulic properties of some samples of the unconsolidated weathered overburden aquifer of the study area (Obiefuna and Nur, 2003).

| S/N | Sample name | Location | Hydraulic Conductivity (m/s) x $10^{-3}$ | | | | | Transmissivity ($m^2$/s) x $10^{-3}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| 1 | AA-1 | Durai | 10.57 | 6.78 | 0.40 | 5.91 | 5.00 | 52.85 | 33.90 | 2.00 | 29.55 |
| 2 | AA-2 | Tiruwn | 3.44 | 2.21 | 0.13 | 1.93 | 7.00 | 24.08 | 15.47 | 0.91 | 13.51 |
| 3 | AA-3 | New GRA | 8.66 | 5.54 | 0.33 | 4.85 | 4.00 | 34.64 | 22.16 | 1.32 | 19.40 |
| 4 | AA-4 | Zaranda | 14.71 | 9.43 | 0.56 | 8.23 | 10.00 | 147.10 | 94.30 | 5.60 | 82.30 |
| 5 | AA-5 | Dajin | 8.34 | 5.35 | 0.32 | 4.67 | 26.00 | 216.84 | 139.10 | 8.32 | 121.42 |
| 6 | AA-6 | Durum | 7.11 | 4.56 | 0.27 | 3.98 | 8.00 | 56.88 | 36.48 | 2.16 | 31.84 |
| 7 | AA-7 | Inkil | 7.11 | 4.56 | 0.27 | 3.98 | 24.00 | 170.64 | 109.44 | 6.48 | 95.52 |
| 8 | AA-8 | Wunti | 5.97 | 3.83 | 0.23 | 3.34 | 19.60 | 117.01 | 75.07 | 4.51 | 65.46 |
| 9 | AA-9 | Yelwa | 3.85 | 2.47 | 0.15 | 2.15 | 15.00 | 57.75 | 37.05 | 2.25 | 32.25 |
| 10 | AA-10 | Guni | 1.66 | 1.06 | 0.06 | 0.93 | 6.00 | 9.96 | 6.36 | 0.36 | 5.58 |
| 11 | AA-11 | Dango | 3.31 | 2.12 | 0.13 | 1.85 | 9.50 | 31.45 | 20.14 | 1.24 | 17.58 |
| 12 | AA-12 | Miri | 3.71 | 2.38 | 0.14 | 2.08 | 11.20 | 41.55 | 26.66 | 1.57 | 23.30 |
| 13 | AA-13 | Nassarawa | 2.16 | 1.38 | 0.08 | 1.21 | 12.50 | 27.00 | 17.25 | 1.00 | 15.13 |
| | Mean | | 6.22 | 3.97 | 0.24 | 3.47 | 12.14 | 982.00 | 626.95 | 37.14 | 547.44 |

1. Hazen method (1893) 2. Harleman et al. method (1963) 3. Uma et al. method (1984)
4. Average values 5. Aquifer thickness (in meters).

calcium and chloride contents range between 26 and 65, and between 140 and 185 mg/l respectively. The Iron, zinc and hardness contents of the water samples analyzed showed 7.3 and 10 mg/l for Iron, 0.08 and 0.12 mg/l for zinc, and between 322.6 and 449.9 mg/l for the hardness (Table 3).

From the results of this study, there are two main aquifer units, which were identified, based on analysis of borehole logs and geologic reconnaissance. These are weathered aquifer and the fractured basement aquifer units. The weathered aquifer unit is derived from the partial and/or complete weathering of the granitic rocks. The weathered material consists mainly of gravels, sands, silts and clays. These residual soils extend from Toro to Bauchi and from Liman Katagum to Kafin Madaki. The thicknesses vary from 3m at Liman Katagum to 33m at Toro with an average thickness of about 10.4m (Fig. 3a,b). The depth to static water level varies from 2.3m to 6.4m with an average of about 4.1m.

## CONCLUSION

There are two main aquifer units, which were identified, based on analysis of borehole logs and geologic reconnaissance. These are weathered aquifer and the fractured basement aquifer units. The weathered aquifer unit is derived from the partial and/or complete weathering of the granitic rocks.

Table 3: Summary of the geochemical properties for all the zones.

| Location | Sample | pH | Na | Mg | Ca | Fe | Zn | Hardness | Carbonate | $SO_4$ | $Cl_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | N0. | Value | (Mean) | (Mean) | (Mean) | (Mean) | (Mean) | (Mean) | $HCO_3/8CO_3$ | (Mean) | (Mean) |
| | | (Mean) | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | Alkalinity | mg/l | mg/l |
| Yelwa | HW-1 | 7.00 | 55.00 | 85.00 | 26.00 | 7.30 | 0.10 | 414.95 | 15.00 | 95.00 | 150.00 |
| New G.R.A | HW-2 | 7.10 | 50.00 | 80.00 | 30.00 | 8.50 | 0.10 | 404.35 | 15.00 | 90.00 | 145.00 |
| Govt. House | HW-3 | 6.70 | 40.00 | 85.00 | 40.00 | 9.60 | 0.08 | 449.91 | 9.00 | 98.00 | 165.00 |
| Nassarawa | HW-4 | 7.40 | 60.00 | 60.00 | 45.00 | 10.00 | 0.12 | 359.45 | 16.00 | 94.00 | 175.00 |
| Wunti | HW-5 | 7.10 | 35.00 | 55.00 | 60.00 | 9.80 | 0.10 | 376.31 | 13.00 | 100.00 | 170.00 |
| Railway Qtrs | HW-6 | 7.10 | 50.00 | 45.00 | 65.00 | 8.70 | 0.10 | 347.62 | 13.00 | 105.00 | 155.00 |
| Gombe Road Opp. F.G.G.C. | HW-7 | 6.90 | 45.00 | 60.00 | 55.00 | 9.00 | 0.10 | 384.42 | 9.64 | 110.00 | 140.00 |
| Shadawanka Barrack | HW-8 | 7.00 | 55.00 | 60.00 | 50.00 | 7.50 | 0.10 | 371.93 | 10.00 | 85.00 | 185.00 |
| Tirumn | HW-9 | 7.20 | 60.00 | 45.00 | 55.00 | 7.90 | 0.10 | 322.65 | 14.00 | 85.00 | 180.00 |
| Mean | | 7.10 | 50.00 | 64.00 | 47.33 | 8.70 | 0.10 | 381.29 | 10.89 | 95.78 | 158.89 |
| Standard Deviation | | 0.20 | 8.66 | 15.77 | 13.25 | 0.96 | 0.01 | 37.99 | 2.69 | 8.51 | 14.95 |

Nine boreholes of depths that range between 54 and 149 m, and an average hydraulic conductivity of 0.91 m/day, and transmissivity value of 19.86 $m^2$/day. Geochemical analysis conducted showed a mean sodium and magnesium contents of 50 and 64 mg/l respectively. The average contents of sulphate, calcium and chloride are 95.8, 47.3 and 185.9 mg/l respectively, while the Iron, zinc and hardness indicated 8.7, 0.1 and 381.3 mg/l respectively. The values indicated that the water is of chloride type and is generally of good quality and also suitable for both agricultural and industrial purposes.

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